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Hexachlorobenzene

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16. ABSTRACT

The properties, production processes, uses, and emission sources for hexachlorbenzene are explained in this report. The environmental effects, health hazards, and current control technologies are discussed. The problems of the longevity of the hexachlorobenzene molecule and past hexachlorobenzene contamination are discussed and areas requiring further study are pointed out.

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STATUS ASSESSMENT OF TOXIC CHEMICALS: HEXACHLOROBENZENE

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report contains a status assessment of the air emissions, water pollution, health effects, and environmental significance of hexachlorobenzene. This study was conducted to provide a better understanding of the distribution and characteristics of this pollutant. Further information on this subject may be obtained from the Organic Chemicals and Products Branch, Industrial Pollution Control Division.

Status assessment reports are used by IERL-Ci to communicate the readily available information on selected substances to government, industry, and persons having specific needs and interests. These reports are based primarily on data from open literature sources, including government reports. They are indicative rather than exhaustive.

David G. Stephan
Director
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ABSTRACT

Hexachlorobenzene (HCB) can be produced as either a waste or a byproduct from fourteen types of industrial processes. Although 1,450 metric tons were produced in 1975, present HCB production and use quantities are unknown. Emissions from manufacture are unknown.

Residues from the manufacture of chlorinated solvents and pesticides represent the most prominent source of HCB, and the emissions are estimated at 1,000 to 3,900 metric tons/yr. Air and water, near waste-containing-HCB disposal sites have been observed to contain up to 24 $\mu g/m^3$ and 90 mg/m^3 of HCB, respectively. Soil samples near these same sites contain from 11 $\mu g/g$ to 3,000 $\mu g/g$. Due to the persistence of HCB, levels do not decline rapidly.

Present control methods consist of incineration, deep-well injection, and landfill. Incineration is most effective at 1,300°C and 0.25 s. While these control methods could be applied to current waste streams, environmental pollution from past HCB waste holding areas may represent a continuing problem because HCB is stable and sublimes in air.

The only existing regulations on HCB are prohibition of ocean dumping and limiting HCB in animal carcasses to 0.5 ppm.

Future studies should include confirmation of production quantities and use along with emissions estimates, concentrations in pesticides and chlorinated solvents, and methods for removing HCB from wastes such as sludges and wastewater. HCB has been used as a fungicide in the United States with more than 6.9 metric tons used in 1971. Concern over the safety of HCB use, in late 1972, may have eliminated continued use of HCB in grain or food chain products.

This report was submitted in partial fulfillment of Contract 68-03-2550 by Monsanto Research Corporation under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period November 1, 1977 to December 31, 1977. The work was completed as of January 20, 1978.

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CONVERSION FACTORS AND METRIC PREFIXES[a]

CONVERSION FACTORS

To convert from	to	Multiply by
Degree Celsius (°C)	Degree Fahrenheit (°F)	$t_F^\circ = 1.8\ t_C^\circ + 32$
Kilogram (kg)	Pound-mass (pound-mass avoirdupois)	2.204
Kilometer^2 (km^2)	Mile^2	3.860×10^{-1}
Meter^3 (m^3)	Foot^3	3.531×10^{1}
Meter^3 (m^3)	Gallon (U.S. liquid)	2.642×10^{2}
Metric ton	Pound-mass	2.205×10^{3}
Pascal (Pa)	Pound-force/inch^2 (psi)	1.450×10^{-4}

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	Example
Centi	c	10^{-2}	1 cm = 1×10^{-2} meter
Kilo	k	10^{3}	1 kg = 1×10^{3} grams
Milli	m	10^{-3}	1 mm = 1×10^{-3} meter

[a] Standard for Metric Practice. ANSI/ASTM Designation: E 380-76$^\epsilon$, IEEE Std 268-1976, American Society for Testing and Materials, Philadelphia, Pennsylvania, February 1976. 37 pp.

ACKNOWLEDGEMENT

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SECTION 1

INTRODUCTION

Hexachlorobenzene (HCB) is toxic to man and has been shown to cause liver tumors and dysfunction in hamsters. It is only marginally produced in the United States and generally as a byproduct of other chlorinated hydrocarbons manufacture. Concern over HCB in the environment was heightened by high levels found in beef cattle in 1972. The purpose of this report is to summarize existing information on the production, uses, emissions, health effects, control technology, and regulatory action with respect to HCB. The fate and route of HCB in the environment is also summarized.

SECTION 2

SUMMARY

Serious incidents of environmental contamination have been observed involving hexachlorobenzene (HCB) wastes and products. Despite steps to reduce environmental discharges of hexachlorobenzene, environmental contamination persists. HCB is toxic to man and presents a hazard in the environment. It is highly resistant to chemical, biological, and physical degradation and is persistent throughout the environment. It is apparently accumulated in food chains. There are recent reports of the occurrence of hexachlorobenzene in human adipose tissues (95% of those sampled), the food supply, industrial effluents, and drinking water. Hexachlorobenzene has recently been shown to be a carcinogen in hamsters. Its chronic toxic effects are exhibited by liver dysfunction in these animals.

Hexachlorobenzene is not a significant item of commerce and is not produced as a direct product of a commercial process. It is a specialty chemical which may be recovered as a byproduct. Whether there are any current uses of HCB or whether byproduct HCB is currently recovered for commercial use or distribution is unknown. In 1975, 1,450 metric tons[a] were reported to be produced in the United States.

It has been observed that HCB may transport through the environment due to sublimation from wastes containing HCB. For this reason, waste disposal practices are under scrutiny.

Industrial wastes from manufacture of chlorinated hydrocarbons in the solvents and pesticides industries are the major source of HCB emissions. Emissions estimates range from 1,000 to 3,900 metric tons/yr. These emissions could be reduced by incineration of wastes. Adequate disposal methods appear to be available. A management plan to define regulatory action for control of HCB emissions would have to be directed toward waste streams from organic solvent and pesticide manufacture.

Table 1 summarizes important findings of this assessment on emission sources, extent of the problem, control methods, and regulatory action.

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[a] 1 metric ton = 10^6 grams; conversion factors and metric system prefixes are presented in the prefatory pages of this report.

TABLE 1. HEXACHLOROBENZENE

Emission source	Extent of problem	Control methods	Regulatory action
Production of hexachlorobenzene	Over 100 sites across U.S. may have produced HCB as a by-product or waste.	Incineration at high temperature (1,300°C and 0.25 s).	In 1973, an interim tolerance of 0.5 ppm was set for HCB content in animal carcasses by the EPA.
Waste disposal at chlorine, carbon tetrachloride, perchloroethylene, trichloroetnylene, Dacthal, atrazine, propazine, simazine, vinyl chloride, pentachloronitrobenzene, hexachloroethane, diethyl tetrachloroterephthalate, mirex, and other chlorinated hydrocarbon producing plants.	Airconcentrations of 1 $\mu g/m^3$ to 24 $\mu g/m^3$, observed waste disposal sites.	Deep-well injection.	The state of Louisiana required better solid waste disposal practices.
	Water concentrations of 1 mg/m^3 to 90 mg/m^3 observed in wastewaters leaving these plants.	Landfill using barriers and 1 m to 2 m of cover.	Dacthal and other pesticides containing HCB are under review by EPA.
	Soil samples taken beyond plant boundaries varied from 11 µg/g to 3,000 µg/g.		Ocean dumping of HCB-laden wastes is prohibited.
	From 1,000 to 3,900 metric tons of HCB are estimated to be emitted per year (1972 to 1977).		
Uses include: grain fungicide, pyrotechnic compound chemical intermediate, wood preservative, feedstock for pentachlorophenol, and peptizing agent in rubber manufacture.	6.9 metric tons used as grain fungicide in 1971.		Designated a priority pollutant under the Federal Water Pollution Control Act.

Based upon information presented in this report, the following items need to be considered in future studies:

- Determination of the concentration of HCB in various pesticide products such as atrazine, propazine, simazine, Dacthal, pentachloronitrobenzene, or mirex.
- Methods for removing HCB from wastes such as sludges and process wastewater.
- Identification of the amount of HCB used in dye manufacture, organic synthesis, and rubber manufacture as well as its use as a grain fungicide and wood preservative.
- Identification and production quantity of locations, if any, which presently manufacture HCB.
- The potential for chronic effects at low-level exposure of hexachlorobenzene.
- Methods to contain or treat existing HCB which has been disposed as waste in landfill from chlorinated solvents manufacture.

SECTION 3

SOURCE DESCRIPTION

CHEMICAL AND PHYSICAL PROPERTIES

Hexachlorobenzene or perchlorobenzene (C_6Cl_6) is a white powder that is soluble in benzene, ethyl ether, and chloroform; sparingly soluble in cold alcohol; and insoluble in water. It has a molecular weight of 284.80, a melting point of 227°C, boiling point of 325°C, and flash point of 243°C. It sublimes rapidly at ambient temperatures, 0 to 30°C (1, 2).

PRODUCTION

Hexachlorobenzene (HCB) is a specialty chemical recovered as a byproduct from proprietary chlorinated hydrocarbon processes (3). Two companies produced HCB in 1976 (4). These were Hummel Chemical Co., Inc., in South Plainfield, New Jersey and Dover Chemical Corp. in Dover, Ohio. Stauffer Chemical Company has also produced HCB in recent years. Recent information indicates that HCB is no longer produced at these sites (5); however, the 1977 Buyers Guide issue of "Chemical Week" lists three producers

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(1) Stecher, P. G., M. Windholy, D. S. Leathy, D. M. Bolton, and L. G. Eaton. The Merck Index, Eighth Edition. Merck and Company, Inc., Rahway, New Jersey, 1968.

(2) Hawley, G. G. Condensed Chemical Dictionary. Eighth Edition. Van Nostrand Reinhold Co., New York, New York, 1971.

(3) Mumma, C. E., and E. W. Lawless. Survey of Industrial Processing Data. Task 1 - Hexachlorobenzene and Hexachlorobutadiene Pollution from Chlorocarbon Processing. EPA-560/3-75-003, U.S. Environmental Protection Agency, Washington, D.C., June 1976. 187 pp.

(4) 1977 Directory of Chemical Producers United States of America. Stanford Research Institute, Menlo Park, California, 1977. 1059 pp.

(5) 1977 Directory of Chemical Producers United States of America. January to September Supplement. Stanford Research Institute, Menlo Park, California, 1977. 73 pp.

of HCB: Dover Chemical Corporation; Rhodia, Incorporated, Chemical Division; and Stauffer Chemical Company, Industrial Chemicals Division (6).

Only occasional and fragmentary production statistics are published for higher chlorobenzenes, such as hexachlorobenzene. A data base prepared by Radian Corporation listed HCB production as 1,450 metric tons in 1975 (7).

PROCESS DESCRIPTION

Methods for production of HCB are proprietary and limited information is available. At Stauffer Chemical in Louisville, Kentucky, HCB has been recovered from a byproduct that contains 80% HCB. The remainder of the tar is recycled to the process. Processes for direct production of HCB use either benzene or hexachlorocyclohexane ($C_6H_6Cl_6$) as the raw materials.

In one of the basic processes, benzene is reacted with excess chlorine in the presence of ferric chloride at 150°C to 200°C as shown in Figure 1. The reaction products are scrubbed with water to remove hydrogen chloride. The gaseous chlorobenzenes are recycled to the initial reactor. The reaction products are cooled to 100°C to allow the HCB to crystallize (3). A continuous process for HCB production by this method has been patented by Olin Mathieson Corporation (8).

In another major process, isomers of hexachlorocyclohexane are refluxed with sulfuryl chloride (SO_2Cl_2) or chlorosulfonic acid ($HClSO_3$). A ferric chloride or an aluminum chloride catalyst is employed. Reaction temperatures are 130°C to 200°C. The reaction mixture is cooled to crystallize the HCB, which is filtered, centrifuged, and washed. A schematic for this process is given in Figure 2 (3).

Hexachlorobenzene is formed as a byproduct of hexachloroethane production and is also produced as one of a group of coproducts formed when ethylene is substituted for methane in the Hüls process for carbon tetrachloride production (8). In addition, HCB can be produced as a byproduct, waste, or impurity with the following chemicals: chlorine, perchloroethylene, trichloroethylene, Dacthal, atrazine, propazine, simazine, vinyl chloride, pentachloronitrobenzene, and Mirex (3).

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(6) 1977 Buyers Guide. Chemical Week, 119(17), 1976.

(7) Garner, D. N. and P. S. Dzierlenga. Organic Chemical Producers' Data Base Program. Radian Corporation, Austin, Texas, 1976.

(8) Kirk-Othmer Encyclopedia of Chemical Technology, Second Edition, Vol. 5. John Wiley & Sons, Inc., New York, New York, 1964. 884 pp.

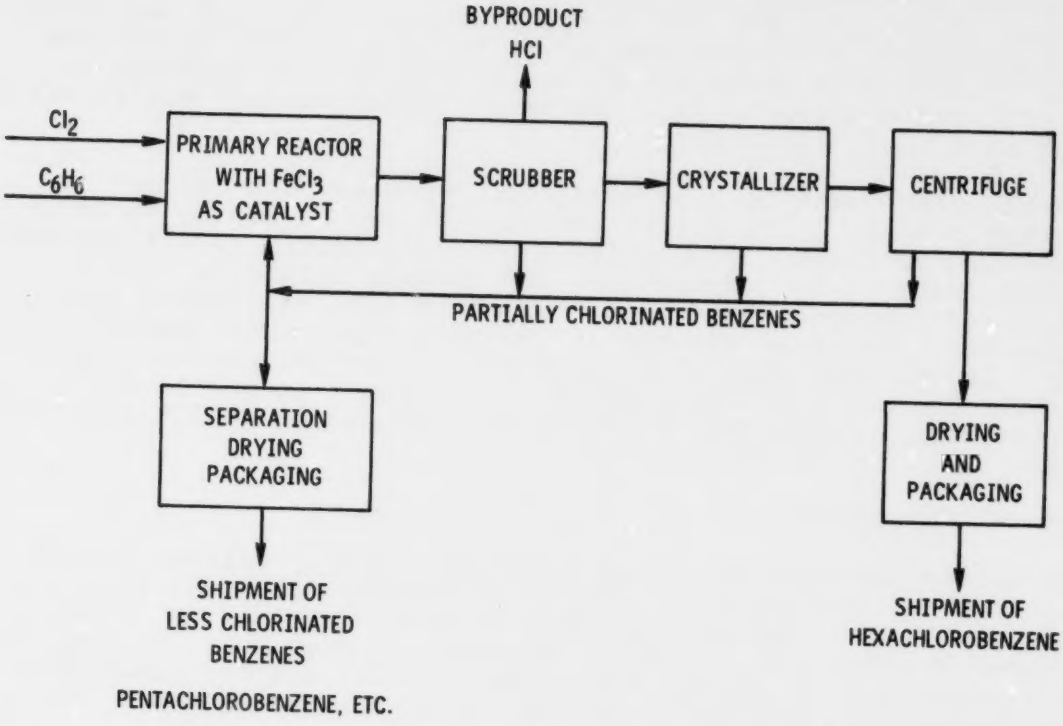

Figure 1. Production schematic for hexachlorobenzene by chlorination of benzene and chlorobenzenes (3).

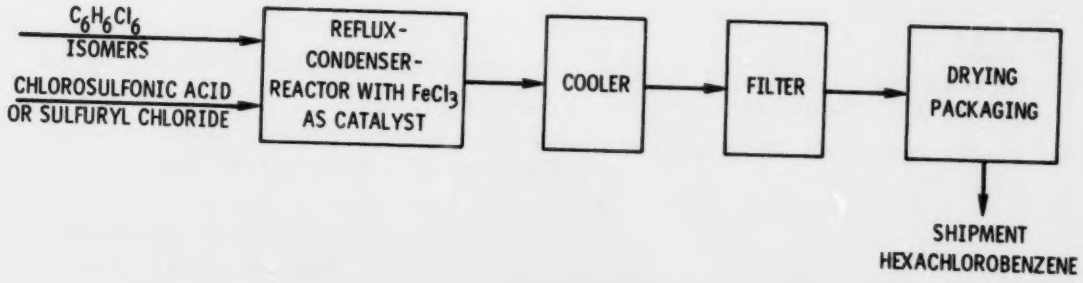

Figure 2. Production schematic for hexachlorobenzene from hexachlorocyclohexane (3).

USES

Hexachlorobenzene has been used in the past as a fungicide to control wheat bunt and smut fungi of grains. The U.S. Department of Agriculture estimated that about 6.9 metric tons of HCB was used in 1971 as a grain fungicide, principally in Washington, Oregon, and California (9). It is not clear whether HCB is still used as a grain fungicide.

Several other uses for HCB have been reported, but may not be current. These applications include the use of HCB as an additive for pyrotechnic compounds, a porosity controller, a chemical intermediate in dye manufacture and organic synthesis, and a wood preservative. Hexachlorobenzene is also reportedly used as a peptizing agent in nitroso and styrene type rubber manufacturing. It has been used as a feedstock in the production of pentachlorophenol, but this process is no longer in use in the United States. Current estimates of the amounts of HCB used are unavailable (3, 8, 10, 11, 12).

TRANSPORTATION

HCB wastes are transported by forklift truck, pipeline, heated tank trucks, and railcars. Prior to ultimate disposal they are stored as solid waste cubes under plastic cover and in water-covered lagoons (13). Diamond Shamrock in Deer Park, Texas, transports HCB-containing wastes to off-site disposal facilities. The wastes are packaged in sealed containers before being shipped (3).

HCB powder used as a fungicide would have to be transported from its production site to the location where it is used, most likely in small drums. Improper containment during transport can result in HCB emissions into the air via sublimation or dust kickup. HCB emitted during transportation can contaminate soil and water and settle on the surface of vegetation (10).

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(9) Assessing Potential Ocean Pollutants. National Academy of Sciences, Washington, D.C., 1975.

(10) Environmental Contamination from Hexachlorobenzene. EPA-560/6-76-014, U.S. Environmental Protection Agency, Washington, D.C., July 1973. 34 pp.

(11) Wilkins, G. E. End Use Patterns for Significant Organic Chemicals. Radian Corporation, Austin, Texas, July 21, 1976.

(12) Chemical Origins and Markets. G. M. Lawler, ed. Stanford Research Institute, Menlo Park, California, 1967.

(13) Journal of Hazardous Materials, 1(4):343-359, March 1977.

SECTION 4

ENVIRONMENTAL SIGNIFICANCE AND HEALTH EFFECTS

ENVIRONMENTAL SIGNIFICANCE

Sources of Emissions

Fourteen types of industrial processes produce HCB as a waste or byproduct (13). In processes where hexachlorobenzene is recovered as a byproduct, HCB is recovered or recycled to the process. The majority of HCB containing wastes is produced in pesticide and chlorinated solvent manufacture. Processes for the production of perchloroethylene, trichloroethylene, carbon tetrachloride, other chlorinated hydrocarbons, and pesticides produce HCB containing wastes. This waste is in the form of a heavy, tarry residue which contains chlorinated hydrocarbons including HCB. The wastes from perchloroethylene and carbon tetrachloride production reportedly contain 10% to 15% HCB and are disposed in waste dumps. The dumps are then sources of HCB which may be leached or sublimed into the environment.

Production of chlorine gas by electrolysis of NaCl with a graphite anode and mercury cathode may also release HCB. In addition, HCB is contained as a significant contaminant in the pesticides diethyl tetrachloroterephthalate and pentachloronitrobenzene (3, 9, 10). It may also be present in other pesticides. Since HCB sublimes, the use of pesticides may be an important source of HCB. No confirmatory data are available.

Estimated production of HCB wastes is given in Tables 2 and 3. According to one estimate, production of perchloroethylene accounts for about 72% of all HCB formed in the United States and production of carbon tetrachloride, perchloroethylene and trichloroethylene accounts for 89% (3). Results published in 1977 (Table 3) indicate that chlorinated solvent production accounts for about 60% of HCB wastes (13).

Hexachlorobenzene can also be emitted directly into the air from production processes for HCB (10); however, one study shows waste holding areas were often the most significant emission source within the plant area (3).

TABLE 2. ESTIMATED TOTAL QUANTITY OF HEXACHLOROBENZENE CONTAINED IN U.S. INDUSTRIAL WASTES, BYPRODUCTS, AND PRODUCTS IN 1972 (3)

Product	U.S. production, 1,000 metric tons	Estimated HCB produced, metric tons	
		High	Low
Perchloroethylene	334	1,590	794
Trichloroethylene	194	204	104
Carbon tetrachloride	453	182	90
Chlorine	8,660	177	73
Dacthal	0.9	45	36
Vinyl chloride	2,040	12	0
Atrazine, propazine, simazine	51	4	2
Pentachloronitrobenzene	1.4	3	1
Mirex	0.4	0.9	0.4
TOTAL	-[a]	2,200	1,010

[a]Not applicable.

TABLE 3. ANNUAL VOLUME OF HCB WASTES FROM PESTICIDES AND CHLORINATED SOLVENT INDUSTRIES IN 1977 (13)

Industry	Products	Annual production of HCB wastes, metric tons
Pesticide	Dacthal, pentachloronitrobenzene, mirex, simazine, atrazine, propazine.	1,500
Industrial organic chemicals	Chlorinated solvents.	2,400

Environmental Levels

The concentration of HCB in various media is primarily due to solid- or semi-liquid wastes containing HCB. Although contaminated soil has been observed, it is believed to be caused by particulate or vapor HCB in the air (14). In 1975, 46% of the

(14) Li, R. T., J. L. Spigarelli, and J. E. Going. Sampling and Analysis of Selected Toxic Substances. Task 1A - Hexachlorobenzene. EPA-560/6-76-001, U.S. Environmental Protection Agency, Washington, D.C., June 1976. 166 pp.

soil samples collected at 26 locations along a 240 km transect in Louisiana were contaminated with HCB at levels from 20 ppb (parts per billion) to 440 ppb. Although water samples generally contained less than 3 ppb, one sample downstream of an industrial discharge contained 90 ppb. Air immediately adjacent to waste dumps has shown concentrations from 1.0 $\mu g/m^3$ to 24 $\mu g/m^3$. Most of the hexachlorobenzene appeared to be associated with particulate matter although some was found in the gas phase. This may have resulted from volatilization of solid material. Samples collected from pastureland near a known production site revealed concentrations in the vegetation from 0.01 ppm (parts per million) to 630 ppm and in the soil from 0.01 ppb to 300 ppb (10).

In 1974 and 1975, soil, water, and organism samples were collected periodically from sites in southeastern Louisiana, with emphasis along the Mississippi River and an industrial region of known contamination near Geismar, Louisiana. Maximum HCB concentrations in water from the two areas were 90 mg/m^3 and 75 mg/m^3 (ppb). Maximum concentrations in soil were 874 $\mu g/kg$ and 53,130 $\mu g/kg$ (ppb) (15).

Sampling tests at nine industrial plants representing six industries (perchloroethylene, trichloroethylene, carbon tetrachloride, chlorine, triazine herbicides, and pentachloronitrobenzene) showed HCB levels as high as 24 $\mu g/m^3$ in the air and 306 mg/m^3 in open wastewater treatment ponds. Levels of HCB in the soil within plant boundaries were greater than 1,000 $\mu g/g$ at three of the plants sampled. The maximum concentration found in air beyond these plant sites was 0.36 $\mu g/m^3$; however, 3 $\mu g/m^3$ was detected at the boundary of another plant. Soil in a cornfield adjacent to another plant site showed a concentration of 11 $\mu g/g$ and more than 3,000 $\mu g/g$ was detected along the boundary road of yet another plant. The observed HCB concentration in water beyond plant property was more than 1 mg/m^3 at two plants (14).

Hexachlorobenzene has been detected in rivers and chemical effluents at various locations (16). Hexachlorobenzene residues have been found in soil, wildlife, fish, and food samples collected from all over the world. In the United States, residues have been reported in birds and bird eggs collected from Maine to Florida, duck tissues collected from across the country, and fish

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(15) Laseter, J. L., C. K. Bentell, A. L. Lacka, D. G. Holmquist, D. B. Condie, J. W. Brown, and R. L. Evans. An Ecological Study of Hexachlorobenzene (HCB). EPA-560/6-76-009, U.S. Environmental Protection Agency, Washington, D.C., April 1976. 74 pp.

(16) Shackelford, W. M. and L. H. Keith. Frequency of Organic Compounds Identified in Water. EPA-600/4-76-062, U.S. Environmental Protection Agency, Athens, Georgia, December 1976. 629 pp.

and fish eggs from the East Coast and Oregon. Animal foods, including chicken feed, fish food, and general laboratory feeds, have been found to contain residues. The frequency of detection of residues in domestic meats has been steadily increasing since 1972, in part because of closer scrutiny. In 1972, beef cattle carcasses in Louisiana were found to contain concentrations as high as 1.5 ppm. The chemical has been detected in trace amounts in only two drinking water supplies. EPA's monitoring of human adipose tissues collected from across the United States reveals that about 95% of the population has trace residues (10). More information on levels of HCB residues found in aquatic organizms and man is available in reports by the National Academy of Sciences (9) and the Midwest Research Institute (3).

Reactions in the Environment

Hexachlorobenzene is a very stable, unreactive, and mobile compound. It apparently does not undergo photochemical reactions in the atmosphere, and it is not hydrolyzed in aqueous solutions. There is no evidence that it is broken down by physical or chemical processes in the environment. It also appears to be largely immune to the biological degradation process. Studies indicate that it is not metabolized to any significant extent, but pentachlorobenzene is a possible metabolic derivative (9).

Since hexachlorobenzene is volatile over water, even at low temperatures, codistillation is a method of dispersal. HCB also sublimes readily and will evaporate if exposed to air under adequate ventilation (9). It readily vaporizes from soil into the air; emissions to the air can in turn contaminate more soil (10). Aerial dispersal may be the major pathway for HCB entering the marine environment (9).

Population Exposed

Hexachlorobenzene has been produced at Dover, Ohio, (estimated population 11,200) South Plainfield, New Jersey, (population 21,300); Louisville, Kentucky (population 706,000) and possibly at other locations. Because of the persistence of HCB, residents of these areas could be exposed to HCB residues resulting from emissions from the plants even if the plants are not currently producing HCB.

Plants that produce HCB as a byproduct or waste are located at over 100 sites throughout the country. Locations and production capacities of these plants are given in a study by Midwest Research Institute (3). (Most of these sites are located in highly industrialized complexes in the South and eastern United States.) Residents of areas near plants that produce HCB as a byproduct or waste may be exposed to HCB emitted into the air or contained in soil. Occupational exposure to HCB could affect

workers at these plants as well as at the plants that directly produce HCB.

HCB has been used as a grain fungicide, especially in Washington, Oregon, and California (9). Because of the persistence of HCB, residues of HCB could exist in soil where treated seed has been planted. The population may also be exposed to HCB from the use of pesticides such as Dacthal and pentachloronitrobenzene that contain HCB as an impurity (9).

HEALTH EFFECTS

Effects on Humans

Evidence of the toxic effects of HCB for humans exists. The death of breast-fed infants and an epidemic of skin sores and skin discoloration were associated with accidental consumption of hexachlorobenzene-contaminated seed grain in Turkey in the mid-1950's. Doses were estimated at 50 to 200 mg/day for several months to two years. Clinical manifestations included weight loss, enlargement of the thyroid and lymph nodes, skin photosensitization, and abnormal growth of body hair. Hexachlorobenzene levels of up to 23 ppb in blood are believed to have contributed to enzyme disruptions in the population of a small community in southern Louisiana in 1973 (10).

Effects on Animals

Long-term (up to 3 years) animal ingestion studies show a detectable increase in deaths at 32 ppm, cellular alteration at 1 ppm, and behavioral alteration between 0.5 ppm and 5 ppm. Apparently, the effective dosage to offspring is increased by exposure to the parent. A 12% reduction in offspring survival results when exposure to very low levels had been continuous for three generations. Teratogenic effects appear minimal (10).

A recent feeding study in hamsters showed that hexachlorobenzene causes hepatomas (liver tumors) and hemangioendotheliomas (capillary tumors). Doses of 50 ppm, 100 ppm, and 200 ppm of hexachlorobenzene mixed with feed were used. Hepatomas were observed at all dose levels, at rates and latencies appearing to be dose related. Hemangioendotheliomas appeared only in the high dose group (9% in females, 34% in males), and three of these tumors in males metastacized (10).

Additional toxicological information on HCB is given in Table 4 (17).

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(17) Registry of Toxic Effects of Chemical Substances, 1976 Edition. H. E. Christensen, E. J. Fairchild, eds. U.S. Department of Health, Education, and Welfare, Rockville, Maryland, June 1976. 1245 pp.

TABLE 4. TOXIC EFFECTS OF HEXACHLOROBENZENE (17)

Oral lethal dose (50 percent kill) mg/kg body weight	Animal
3,500	Rat
4,000	Mouse
1,700	Cat
2,600	Rabbit

Bioaccumulation in catfish has been observed to be extremely high, and the half-life in cattle and sheep is almost 90 days (10).

SECTION 5

CONTROL TECHNOLOGIES

The major source of environmental contamination from HCB is wastes from plants producing other chemicals. Some work has been done on the development of environmentally sound disposal methods for waste containing HCB. A study by Midwest Research Institute includes a survey of waste disposal techniques practiced by industries that produce wastes containing HCB (3). Three methods are currently being used for disposal of these wastes: landfill, deep-well injection, and incineration.

High temperature incineration appears to be the best alternative. Deep-well injection may create geological fractures resulting in contamination of aquifers (3). Landfill disposal of wastes containing HCB can lead to migration of HCB via water and sublimation of HCB into the air (10). Virtually all the HCB can be destroyed in high temperature incineration systems (3). Incineration of chlorinated hydrocarbons such as HCB is generally carried out at temperatures around 1,300°C with a retention time of about 0.25 s. Several types of incinerators are available. Most hexachlorobenzene waste is a viscous liquid at ambient temperature and can be incinerated in rotary kiln incinerators or in fluidized sand bed incinerators. Exhaust gases from incineration must be scrubbed in high energy scrubbers with caustic soda or lime solution to neutralize HCl and other acids evolved (3). Dow Chemicals uses a proprietary "thermal oxidizer" (steam-oxygen fed incinerator) to incinerate wastes containing HCB. Products of the incineration are hydrogen chloride, carbon dioxide, and water. More than 99% of the HCB is reportedly destroyed (10).

Plastic sheets are reportedly effective in reducing particulate emissions of HCB from waste storage areas, but vapor emissions of HCB from such areas may still be high. Hexachlorobenzene content in water was reportedly reduced about 50% at two plants sampled by detaining wastes in holding ponds or treatment canals (14). A discussion and evaluation of methods used for treatment

and disposal of wastes containing HCB is given in a report done by TRW Corporation for EPA (18).

A recent report indicates that land disposal is the most prevalent disposal method. Land disposal was characterized as environmentally acceptable if soil covers of 1 m to 2 m and intermediate plastic layers were employed to reduce the sublimation rate. Selection of a site with geological characteristics that would provide for leachate containment is also necessary (13).

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(18) Quinlivan, S., M. Ghassemi, and M. Sontry. Survey of Methods Used to Control Wastes Containing Hexachlorobenzene, EPA-530/SW-120C, U.S. Environmental Protection Agency, Washington, D.C., November 1975. 92 pp.

SECTION 6

REGULATORY ACTION IN PROGRESS

In the wake of widespread hexachlorobenzene contamination of cattle in Louisiana in 1973 and concern over possible contamination of sheep in California, EPA established an interim tolerance level of 0.5 ppm. Concurrently, the State of Louisiana and several companies took immediate steps to improve solid waste disposal practices from manufacturing. Also, supplies of Dacthal containing 10% HCB were voluntarily withdrawn from the California market.

As soon as the needed toxicological data are available, a food tolerance will be established. Also, all pesticidal uses will be reviewed, including pesticides which contain hexachlorobenzene as a contaminant. Studies of land and other disposal methods have been completed. Ocean dumping of hexachlorobenzene-laden tars is prohibited (10).

It has also been designated a priority pollutant under the Federal Water Pollution Control Act.

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